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Connecting MicroPower to the Grid

A status and review of
micropower interconnection issues and
related codes, standards and guidelines in Canada



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Natural Resources
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Executive Summary

There is an accelerating world demand for environmentally friendly power, generated with photovoltaic, wind turbines, fuel cells and microturbines. There is a huge potential market among homeowners and small business operators for these "green" micropower sources.

Micropower generators have the potential to improve air quality, reduce environmental damage related to coal or oil-fired generation, and provide greater security in the event of energy shortages.

Also, the connection of small, privately-owned electricity generators to the public power system has many benefits for Canada's economy. However, the challenge for governments and regulators is to allow this new industry to grow in a way that is both safe and efficient.

To that end, Canadian provinces and territories must have appropriate technical standards in place. Such standards allow for consistent manufacturing and installation practices, and reduce the costs, paperwork and safety problems that now prevent many people from using these new technologies. In this respect, this document summarizes the state of four micropower sectors, namely: photovoltaics, fuel cell, wind turbine and microturbine, by identifying the safety and power quality standards and related codes that now exist, those that are lacking in Canada, as well as those in the international community that can serve as references for Canada.

Photovoltaic (solar) panels are a well-established technology, but rules that were designed for large capacity generators often constitute a huge barrier to the marketing of small rooftop systems. Requirements (code and standards) need to be reviewed to cope with the new reality of small residential systems application.

Sommaire

La demande mondiale pour les sources d'énergie propre est en forte hausse, que ce soit l'énergie photovoltaïque, les éoliennes, les piles à combustibles ou les microturbines. Le marché potentiel de ces sources de microproduction d'énergie est particulièrement évident dans les secteurs résidentiel et de la petite entreprise.

La microproduction d'énergie offre d'intéressantes perspectives pour atténuer le recours qu'a le Canada aux énergies produites à l'aide de combustibles fossiles; elle permet aussi d'atténuer les inconvénients environnementaux engendrés par les centrales activées au charbon ou au pétrole, notamment en matière de qualité de l'air, tout en donnant de meilleures garanties de sécurité en cas de pénurie d'énergie.

De plus, l'addition d'énergie électrique au système public d'approvisionnement par de petits producteurs privés présente de nombreux avantages pour l'économie canadienne. Le défi des gouvernements et des organismes de réglementation demeure toutefois de permettre la croissance de cette industrie naissante dans le respect d'une pratique sécuritaire et efficace.

À cette fin, les provinces et les territoires canadiens doivent se doter de normes technologiques bien définies. De telles normes permettront d'établir des règles d'installation et de production uniformes, tout en réduisant les coûts, la paperasse et les risques inhérents à la sécurité; autant de facteurs qui nuisent au développement de ces nouvelles technologies. Dans cette optique, le présent document fait un survol de quatre méthodes de microproduction, soit : la technologie photovoltaïque, les piles à combustible, les éoliennes et les microturbines; on y fait état des codes et des normes existants en matière de sécurité et de qualité de l'énergie ainsi que des normes manquantes au Canada en plus d'identifier les normes sur la scène internationale qui peuvent servir de points de repère à l'industrie canadienne.

La technologie photovoltaïque est désormais bien connue mais les règles établies pour la production à grande capacité deviennent souvent un obstacle important à la mise en marché d'appareillage destiné aux applications résidentielles. Les exigences (réglementations et normes)

Fuel cells are known for their potential in powering vehicles, without hydrocarbon pollution. Their high efficiency also opens up opportunities for large-scale industrial generation and residential / portable applications, producing both electricity and heat. Standards must keep pace with new fuel cell technologies that are beginning to be commercialized, and others, such as those for pressure equipment, need to be internationalized. International standards are also needed for fuel storage pressure vessels.

As for wind energy, standards do exist in Canada, but they have not kept pace with rapid changes in the technology. There is a need to harmonize them to international standards and ensure that cold-weather wind turbine installations issues are addressed.

Microturbines are the newest devices in the field. They are beginning to be used at commercial and industrial sites for combined heat and power generation. This technology has a large market potential because of its lower cost. Many existing standards for stationary engine generators can be used or adapted but the development of standardized guidelines for interconnection with the grid remains an important issue for this industry. Also, further work is needed on standards for small gas compressors.

While these four micropower technologies have to deal with specific requirements, they also share common issues when it comes to interconnection to the grid. Regardless of the electricity generation method, they all use static inverters, which serve as the interface with the utility grid. In that respect, one single initiative can address the issues pertaining to the interconnection of such micropower generators to the grid. Also, the existing standard on the static inverter itself must be upgraded to suit new grid-connected applications and power generation technologies.

doivent être révisées pour s'adapter à cette nouvelle réalité.

Les piles à combustible sont reconnues pour leur application dans le monde du transport, éliminant les désavantages de la pollution par hydrocarbures. Leur grande efficacité met en lumière des occasions d'utilisation à grande échelle en milieux industriel et résidentiel, produisant à la fois l'électricité et le chauffage. Les normes doivent suivre le rythme d'évolution des nouvelles piles à combustible qui se retrouvent sur le marché. Aussi certaines autres normes, dont celles sur les réservoirs sous pression, requièrent d'être revues afin de les rendre compatibles avec les normes internationales et de faciliter les échanges internationaux.

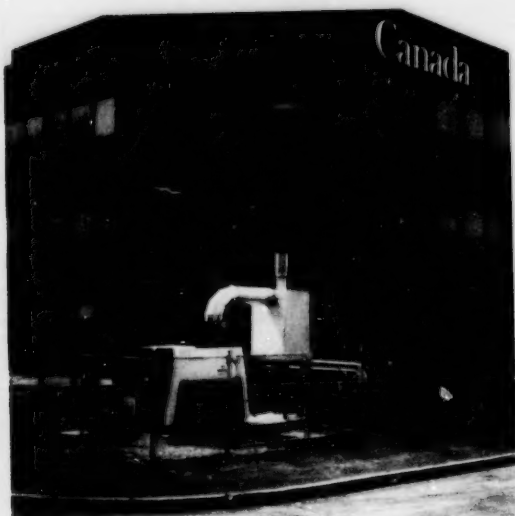
En ce qui a trait aux éoliennes, le Canada a des normes mais celles-ci n'ont pas suivi le rythme rapide d'évolution de cette technologie. Ainsi il y a nécessité de les harmoniser aux normes mondiales tout en s'assurant que les problèmes potentiels associés aux températures froides sont dûment considérés.

Les microturbines constituent une technologie plus récente dans ce domaine. Elles arrivent tout juste sur le marché commercial et industriel de production combinée électricité-chauffage. Cette technologie a beaucoup d'avenir de par ses moindres coûts. Plusieurs normes actuelles touchant les génératrices stationnaires peuvent s'appliquer ou être adaptées mais l'élaboration de principes directeurs uniformisés pour l'interconnexion aux réseaux publics constitue un défi de taille pour l'industrie. De plus, il sera nécessaire de s'attarder davantage aux normes régissant les compresseurs à gaz.

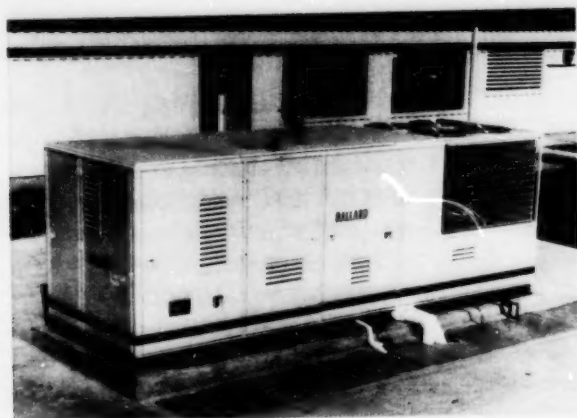
Bien que ces quatre technologies de microproduction d'énergie ont leurs propres exigences à rencontrer, elles font aussi face à un défi commun en matière d'interconnexion au réseau de distribution; toutes ces technologies de production d'électricité utilisent un onduleur électronique à titre d'interface avec le réseau principal. Ainsi une seule action pourrait solutionner la problématique se rapportant à l'interconnexion de tels microproducteurs d'électricité au réseau public. De plus, les normes actuelles couvrant les onduleurs même doivent être rehaussées pour satisfaire aux exigences de ces technologies de microproduction d'électricité et de leurs nouvelles applications reliées au réseau.



Photovoltaic



Microturbine



Fuel Cell



Wind Turbine

1.0 Introduction

A vision of a not so distant future of the electrical network may very well sound like this: An international network of electricity generators based in homes, farms, factories, office buildings and small community facilities. The power devices would be cost-effective and easy to install. The owners would enjoy greater energy security, and receive credit for their excess power.

While this may sound futuristic today, one must admit that deregulation of electricity markets and new products now developed and refined are taking us down a road that is leading us this way. The current issues with the development of this network are not the methods of generating electrical power, as there are a number of micropower options that already exist today, but the mechanisms for sharing it.

The deregulation of the electricity sector in North America provides an opportunity to establish guidelines and policies that will support the widespread use of small renewable energy power and distributed generation sources. Initiatives that are aimed at increasing the market for small renewable and distributed generation have been supported by governments because of three main reasons:

- new technologies often offer cost-effective and efficient solutions with significant environmental benefits;
- there is a huge market potential worth billions of dollars and thousands of jobs; and
- distributed generation improves the reliability of electricity power at the site and delays infrastructure upgrades to the existing network.

Micropower will not replace the need for power generation at large installations by traditional utilities. But it is clear that power needs will continue to grow and there is strong public resistance to additional nuclear and fuel-burning plants, paving the way for small, efficient and clean on-site power generation. However, a number of issues need to be covered to assure a coherent and safe development of this industry. To that extent, safety and power quality standards are an important element of the solution.

Since one of the most important barriers to the adoption and deployment of these new technologies is the lack of harmonised standards and guidelines, Canadian manufacturers and distributors have asked Natural Resources Canada¹ and Industry Canada² to support the establishment of MicroPower Connect³ to facilitate the development of such an approach.

1. The Energy Technology Branch and Renewable Energy and Electricity Division at Natural Resources Canada works with the Canadian industry and associations to remove barriers to the deployment of renewable energy technologies. (www.nrcan.gc.ca/es/)

2. Industry Canada has completed a study entitled *Canadian Electric Power Industry Technology Roadmap: Forecast* and supports the Standards Council of Canada (SCC) in an effort to remove international trade barriers that are caused by lack of international standards. (www.ic.gc.ca)

3. MicroPower Connect is an industry lead initiative managed by Electro-Federation Canada (EFC). EFC's members represent key players in the electrical, electronics, appliance and telecommunications industries. As a broadly based association, EFC stages a dialogue on issues affecting the electro-technical businesses, including standards. (www.micropower-connect.org)

About this report

This report was prepared as an initial activity to provide technical information to stakeholders that will be collaborating on the development of a national guideline for the interconnection of micropower generation in Canada. Industry experts from four micropower technologies (photovoltaic, wind, fuel cell, and microturbines) contributed to the preparation of this standards and codes review. The goal of the report is to identify areas where there is significant overlap in the needs identified and common barriers that the industry must overcome.

Section 2 of this report describes the safety, power quality, and interconnection issues that are common to most on-site generator systems. Sections 3-6 provides a review of photovoltaic, fuel cell, microturbine and wind turbine technology standards and codes. Section 7 provides a compilation of the standards and codes of the four technologies for comparison. Finally, Section 8 concludes with common issues and provides an overview of the principal barriers.

2.0 Safety, Power Quality and Interconnection Issues⁴

In Canada, all electrical and gas products installed must be certified for intended use. For that reason there exists a number of safety and performance standards according to which the products are certified. Similarly, there exist standards and codes that specify the requirements for the installation and interconnection to the grid of electrical systems. The following explains some of the technical issues addressed by the standards and codes covering the safety, power quality and interconnection aspects of micropower technologies.

2.1 Islanding

One of the most important safety issues for small customer-sited systems is a condition called islanding. Islanding is where a portion of the utility system that contains both loads and a generation source is isolated from the remainder of the utility system but remains energised. When this happens with a distributed power system, it is referred to as supported islanding. The safety concern is that if the utility power goes down (perhaps in the event of a major storm), a distributed generation system could continue to supply power to a local area. While a utility can be sure that all of its own generation sources are either shut down or isolated from the area that needs work, an island created by a residential system can be out of their control.

There are a number of potentially undesirable results of islanding. The principal concern is that a utility line worker will come into contact with a line that is unexpectedly energised. Although line workers are trained to test all lines before working on them, and to either treat lines as live or ground them on both sides of the section on which they are working, this does not remove all safety concerns because there is a risk when these practices are not universally followed.

Fortunately, static inverter technology developed for grid-interactive systems is now specifically designed so that there is no chance of an undesired supported island stemming from an interconnected residential or small commercial systems. This feature is referred to as anti-islanding. Grid-tied inverters monitor the utility line and shut themselves off as quickly as necessary in the event that abnormalities occur on the utility system.

2.2 Manual Disconnect

An external manual lockable disconnect switch ("manual disconnect") in the interconnection context is a switch external to a building that can disconnect the generation source from the utility line. The requirement for a manual disconnect, stems from utility safe working practices that require disconnecting all sources of power before proceeding with certain types of line repair.

4. Adapted from "Connecting to the Grid - A Guide to PV Interconnection Issues", IREC Third Edition 2000, by Chris Larsen, Bill Brooks and Tom Starrs.

Whether a manual disconnect for small systems, such as photovoltaic (PV) systems, using certified inverters should be required has been the source of considerable debate. In strict safety terms, a manual disconnect is not necessary for most modern systems because of the inverter's built-in automatic disconnect features as discussed in the previous section. Both the Canadian Electrical Code (CE Code) and the National Electrical Code (NEC) in the United States, refers to the need for an additional switch that is (1) external to the building, (2) lockable by utility personnel, and (3) offers a visible-break isolation from the grid. As such, a manual disconnect is an additional means of preventing an islanding situation. And, the key from the utility perspective is that the switch is accessible to utility personnel in the event of a power disruption when utility line workers are working on proximate distribution system lines. In addition, in many situations, utility line workers can provide redundant protection against islanding by removing a customer's meter from the meter socket. Still, many utilities require a separate, external manual disconnect.

While the cost of installing such a switch is not large relative to the overall cost of a micropower system, a PV system for example, when compared to expected energy savings from the system, such a switch is relatively expensive. Also, for systems located on the top of tall buildings, such a switch becomes very expensive. In the USA, some state-level net metering and interconnection rules require that the utility pay for the installation of a manual disconnect. In New Mexico, use of the meter is an optional alternative to a separate switch while in many other states a manual disconnect is not required, at least for small systems; that is the case of California, New Jersey, Washington, and Nevada. Also, some utilities, such as those owned by the New England Electric System, have established their own interconnection guidelines that do not require an external manual disconnect for small systems.

2.3 Power Quality

Power quality is another technical concern for utilities and customer-generators. In North America, residences receive alternating current (AC) power at 120/240 volts at 60 cycles per second (60 Hz), and commercial buildings typically receive either 120/240 volts or three-phase power depending on the size of the building and the types of loads in the building. Power quality is important because electronic devices and appliances have been designed to receive power at or near these voltage and frequency parameters, and deviations may cause appliance malfunction or damage. Power quality problems can manifest themselves in lines on a TV screen or static noise on a radio, which is sometimes noticed when operating a microwave oven or hand mixer. Noise, in electrical terms, is any electrical energy that interferes with other electrical appliances. As with any electrical device, an inverter, which converts the DC power from the generation side into usable AC power for a house, potentially can inject noise that can cause problems.

In addition to simple voltage and frequency ranges, discussions on power quality include harmonics, power factor, DC injection, and voltage flicker. Harmonics generically refers to distortions in the voltage and current waveforms. These distortions are caused by the overlapping of the standard waves at 60 Hz with waves at other frequencies. Specifically, a harmonic of a sinusoidal wave is an integral multiple of the frequency of the wave. Total Harmonic Distortion (THD) is summation of all the distortions at the various harmonic frequencies.

Power factor is a measure of "apparent power" that is generated when the voltage and current waveforms are out of synch. Power factor is the ratio of true electric power, as measured in watts, to the apparent power, as measured in kilovolt-amperes (kVA). The power factor can range from a low of zero when the current and voltage are completely out of synch to the optimal value of one when the current and voltage are entirely in synch. The terms "leading" and "lagging" refer to whether the current wave is ahead of or behind the voltage wave. Although not strictly the case, power factor problems can be thought of as contributing to utility system inefficiencies.

DC injection occurs when an inverter passes unwanted DC current into the AC or output side of the inverter. Voltage flicker refers to short-lived spikes or dips in the line voltage. A common manifestation of voltage flicker is when lights dim momentarily. It is important to note, however, that grid-interactive inverters are tested to limit THD and generally do not create DC injection or voltage flicker problems.

2.4 Interconnection

Perhaps the number one interconnection barrier for small renewable systems has been the lack of uniformity in interconnection standards from utility to utility. This is a result of the traditional discretion given to utilities to deal with their own generation, transmission, and distribution systems.

To be more accurate, it is a problem of many utilities not having any standards at all for small grid-tied generators. A recent survey done in the USA showed that only a handful of large utilities have any small generator interconnection standards. In the case where a utility has no small generator standards, interconnection is addressed on either a case-by-case basis or through existing standards usually used for larger industrial systems. However, it is beyond the means of most prospective residential or small commercial system owners to hire a professional engineer and attorney for the interconnection of a small grid-tied system that is intended simply to offset a portion of the owner's electricity use.



Photo courtesy of ARISE Technologies Corporation

A 5 kWp grid-connected PV array and solar thermal collectors provide electricity and heat for this residence in Waterloo, Ontario.

Photovoltaic modules convert solar radiation directly into electricity (DC power) through light sensitive semiconductor devices. This DC power can be used directly, stored in batteries or, for convenience and compatibility with the grid and most home appliances, converted to AC power. In the latter case a central inverter or individual inverters integrated onto each module are used.

3.0 Photovoltaic Technical Issues: Safety, Power Quality, and Codes

Overview

In Canada there are a limited number of grid-tied photovoltaic (PV) systems installed to date. However, in the long term there is a large potential for such systems. In Japan 17,500 PV rooftop systems had already been installed on residences between 1993 and 1999. This represents a capacity of 40 MW of on-site power generation and an additional 14,000 systems were planned in 2000. Germany also has an aggressive PV rooftop program and in 1999 over 3,400 systems were installed and represents 8.5 MW of PV power capacity. When thousands of systems are installed every year, it is too costly and time consuming for utilities to conduct case-by-case analysis of each grid-tied system. Much like the other countries, an important step to developing the PV market in North America is the development of simple and uniform standards; this is particularly true for the installation of small PV systems (less than 10 kW).

An important part of the installation issues also has to do with the electricians and electrical inspectors who do not regularly deal with DC circuits and emerging technologies such as PV systems. Furthermore, emerging technologies, as such, are not always properly dealt with by existing codes and standards that support the installation and inspection of safe distributed generation systems. The status on current and under development Canadian codes and standards provided below is intended to show the progress being made as well as to identify remaining gaps in these areas.

3.1 Fuel Source and Storage

In the case of PV systems, the energy source comes from the sun in the form of light, therefore there are no special requirements or standards that apply to the fuel, nor are there any issues regarding the storage of the fuel used by such a system.

3.2 DC Generation

3.2.1 Equipment Standards

PV modules

There exists no Canadian standards nor is there any foreign standard officially recognised in Canada with respect to safety of PV modules. Because of this lack of standard on PV module safety in Canada, NRCan requested that Underwriters' Laboratory of Canada (ULC) initiate a review and development of an ORD (Other Recognised Document) based on the US standard: UL 1703 – Standard for Flat-Plate Photovoltaic Modules and Panels. The requirements of the existing UL 1703 standard cover flat plate PV modules and panels intended for installation on or integral with buildings or to be free standing. Most large PV module manufacturers have already had their products tested to UL 1703 in order to have them listed for sale in

the US. These products are also imported to Canada. The adoption of UL 1703 as an ORD in Canada is an interim solution until an international standard is developed.

Canadians are participating in the development of an international safety standard for PV modules and panels. The committee draft (IEC 61730 Part I and Part II) is currently being circulated for comments to 21 countries that actively participate in the work of the IEC Technical Committee 82. Following a standard approval process will require 2 years, therefore the IEC 61730 is due to be published in 2003.

Power conversion equipment

Power conversion equipment for use in Photovoltaic Systems are partially covered in CSA C22.2 No 107.1. The PV industry initiated a project to revise this standard in 1998. The proposed amendments to the CSA C22.2 No.107.1 include the addition of Section 14 - Power Conversion Equipment for Use in Photovoltaic Systems, and apply to electrical power conversion equipment (on the DC side) designed to be connected in a PV system. Another new section proposed in this CSA standard is discussed in Section 3.3.1.

Other interconnect equipment, such as switches, fuses, and breakers, are covered by existing codes. The existing codes, however, do not take into account the inherently limited PV source and so are often over rated and more costly than necessary. Unless a specific set of standards are developed for this equipment, this issue will continue to make life difficult. This is also true for systems that have battery storage. There is no useful standard for batteries and it is therefore very difficult to get good information from manufacturers.

3.2.2 Installation Requirements

There is a specific section in the Canadian Electrical Code, Part 1 (CEC) dealing with photovoltaics. Section 50 - Solar Photovoltaic Systems was introduced into the CEC in the 1994 edition. Important amendments to update Section 50 have been approved by the Section 50 sub-committee. These have been presented to the CEC Part I Committee for approval. Changes to bring Section 50 in line with modern practises are expected to be published in the CEC 2002 edition.

In Europe many of the installation requirements are developed within the IEC TC64. This technical committee is currently a draft IEC 60364-7-712 : Requirements for special installations or locations – Photovoltaic power supply systems. In the US, the National Electrical Code (NEC) Section 690 provides requirements for PV system installation.

3.3 DC to AC Conversion

3.3.1 Equipment Standards

Static Inverters

Standards covering static inverters exist at all Canadian, American and international levels. Section 10 of CSA C22.2 No. 107.1 already covers stand-alone inverters. This standard has been reviewed and several changes have been submitted for committee vote. A new Section 15 has been proposed to CSA C22.2 No. 107.1 for utility-interconnected inverters. The new section specifies anti-islanding protection and limits of harmonic distortion. The PV industry advisory group recommended the revision of the existing CSA 22.2 No. 107.1 standard and ensured that it is harmonized with the requirements within the American standard UL 1741. If the addition of section 15 is approved, this CSA C22.2 No 107.1 standard will cover grid-tied static inverters up to about 25 kVA. However, if PV grid connected systems installed in Canada are larger, there may be a need in Canada for a standard on static inverters larger than 25 kVA. In the future, preference will be given to adopting internationally recognised standards.

Canadians are currently participating in the development of an international standard project - IEC 62109, Electrical Safety of Static Inverters and Charge Controllers for use in Photovoltaic Systems. This project was initiated and is managed by a UL expert. Safety testing associations, such as CSA (Canada), TUV (Germany), KEMA (Netherlands) and JET (Japan) are also actively participating, therefore these national safety associations intend to move towards the adoption of international standards for static inverters when approved and published. It is expected that the IEC 62109 project will be developed over the next 3 years.

3.3.2 Installation Requirements

The installation of static inverters is covered by the General Clause of the CEC Section 1-12, and 26. These sections cover general rules, grounding, wiring methods and general rules regarding installation of electrical equipment. PV specific requirements are covered in section 50 of the CEC (currently under review).

3.4 Customer-side Interconnection

3.4.1 Equipment Standards

CEC part II includes a number of standards that cover the accessory equipment, namely most of those found under the following categories: General Requirements, Wiring Products and Industrial Products.

3.4.2 Installation Requirements

For the installation of grid connected PV systems, a new clause (50-022) has been proposed for the Canadian Electrical Code Section 50 in order to specify requirements for installation of PV. This is under consideration by the CEC Part I committee.

In the United States, this is covered by the National Electrical Code under sections 690-54 to 690-64.

3.5 Utility-side Interconnection

3.5.1 Equipment Standards

The equipment used for interconnection is generally regular equipment. However the interconnection of distributed generation systems raises a new issue about net metering specifically for meters that can be operated backward.

3.5.2 Installation Requirements

In Canada, the requirements for the interconnection to the utility are covered in the section 84 of the CEC. A very general requirement in clause 002 of section 84 indicates that the interconnection arrangements must be in accordance with the requirements of the supply authority. As a consequence, specific interconnection requirements can be imposed by the local utility. As an example BC Hydro have developed their own requirements for small distributed PV generation – Interconnection of the Solar Photovoltaic Systems to the BC Hydro System. Other utilities also have specific requirements. In the future it would be preferable that harmonised North American and International standards be applied and adopted by supply authorities in Canada. Current rules that were designed for large multi-megawatt capacity generators are a huge barrier to the market introduction of small PV rooftop systems in Canada.

There is a general consensus that exceptions are needed for very small residential systems (under 10 kW) and for small commercial systems (under 100 kW). In North America, IEEE 929 – Recommended Practice for Utility Interface of Photovoltaic Systems and IEEE P1547 – Standard for Distributed Resources Interconnected with Electric Power Systems are the best known references for interconnection. The IEEE 929 is a published standard that is used in most of the net-metering PV programs in the USA, and these do include different requirements for PV systems below 10 kW.

		Have in Canada	Need in Canada	Others (US or International)
FUEL SOURCE / STORAGE	Equipment			
	Installation			
DC GENERATION	Equipment	ULC 1703* CSA C22.2 No. 107.1 new clause 14*		IEC 61730
	Installation	CEC section 50-004 – 50-020*		NEC 690-4 to 690-53
DC-AC CONVERSION	Equipment	CSA C22.2 No. 107.1 new clause 15*	Larger scale inverter safety standard	UL 1741 and IEC 62109
	Installation	CEC general requirements (sections 1-12, 26)		
CLIENT-SIDE INTERCONNECTION	Equipment	CEC Part II relevant standards (Eg. : wiring equip., etc.)		
	Installation	CEC section 50 clause 022*		NEC 690-54 to 690-64
UTILITY-SIDE INTERCONNECTION	Equipment			
	Installation	CEC section 84 Other local requirements	Guideline for interconnection Need exceptions in CEC - 84 for: ≤ 10 kW residential and ≤ 100 kW commercial	IEEE 929 IEEE 1547*

(*) Under consideration

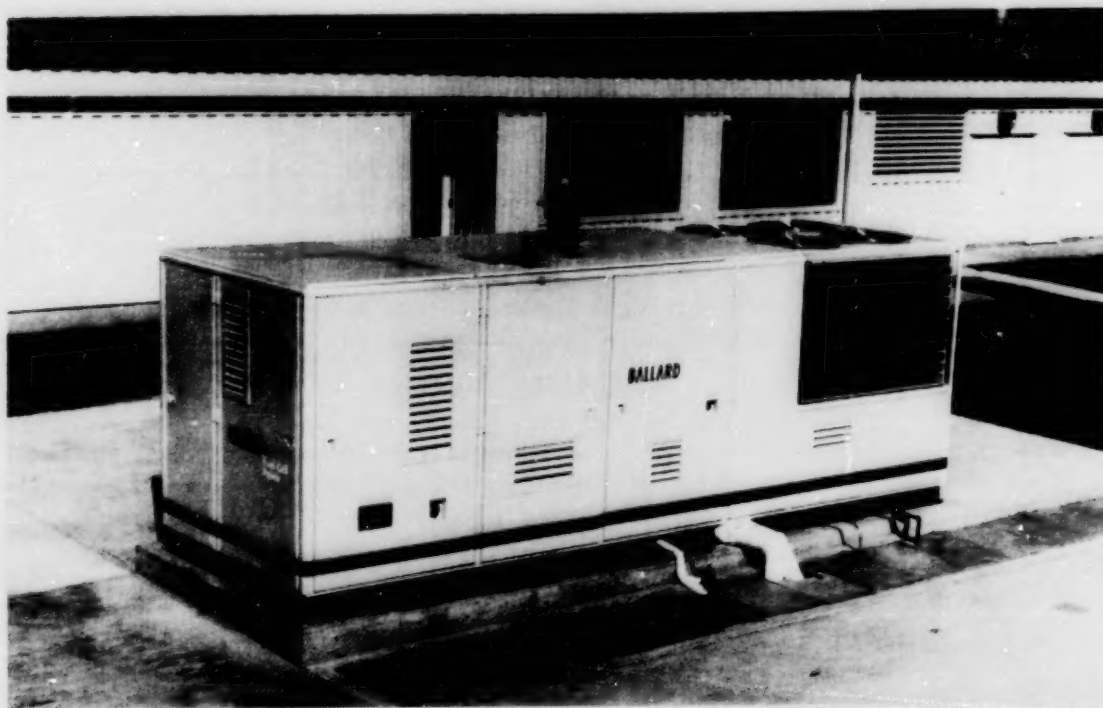


Photo courtesy of Ballard Power Systems

This 250 kW natural gas PEM fuel cell power generator provides power and heat to a building of the Crane Naval Surface Warfare Center in Indiana.

A fuel cell consists of two electrodes sandwiched around an electrolyte. Oxygen passes over one electrode and the hydrogen over the other, generating electricity, water and heat. In principle, a fuel cell operates like a battery and produces DC power; but unlike a battery, a fuel cell does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied.

A fuel cell system which includes a "fuel reformer" can utilize the hydrogen from any hydrocarbon fuel - from natural gas to methanol, and even gasoline. Since the fuel cell relies on chemistry and not combustion, emissions from this type of a system would still be much lower than emissions from the cleanest fuel combustion processes.

4.0 Fuel Cell Technical Issues: Safety, Power Quality, and Codes

Overview

International standards for stationary fuel cell generators are being prepared through IEC TC105, "Fuel Cell Technologies". Canada currently chairs this committee, while Germany is the Secretariat. An IEC construction standard for stationary fuel cell generators is under development by this committee through a project led by the US, while Japan is leading a similar project for the development of a performance measurement standard.

The only published fuel cell standards, that are currently available, are those from the US⁵. The first is ANSI Z21.83⁶, "Fuel Cell Power Plants" covering the construction of stationary generators while the second is NFPA 853, "Standard for the Installation of Stationary Fuel Cell Power Plants". The ASME PTC-50, "Fuel Cell Power Systems" committee is nearing completion of a third US standard, this one for performance measurements⁷.

In addition to standards for the generating technology, standards are being developed for the electrical interconnection of generating units. The first is IEEE P1547, "Standard for Distributed Resources Interconnected with Electric Power Systems", while the second is the proposed IEC standard for hybrid power systems being developed by the Joint Coordination Group of TC 82/21/88^{8,9}. The scope of the IEC standard is expected to be more broad than the IEEE standard and potentially more significant. This IEC standard will consider not only the interconnection of a specific generating technology with an electric utility, but also the interconnection of various distributed generators with each other. These systems, known as hybrid systems, may include wind, photovoltaic, micro-turbine and fuel cell generators used together as a system to compete more effectively with conventional grid technology.

4.1 Fuel Source and Storage

Equipment requirements for some types of fuel cell generators may include the registration of fuel processing pressure vessels. The ISO TC11, "Boilers and Pressure Vessels" committee is currently developing an international registry for pressure vessel standards. Under this system, countries will have the option of registering their pressure vessel standards as being equivalent to the other standards in the registry. Canada became a participating member of TC11 in 2000. The fuel cell industry will benefit by

5. In the EU, a CEN standard has recently been proposed for stationary generators in residential applications with a thermal load up to 70 kW.

6. At the time of writing, management of this standard was being transferred to CSA International.

7. The first draft is scheduled for completion in 2001.

8. These are the IEC Technical Committees for Photovoltaics, Batteries and Wind respectively.

9. This committee met for the first time in January, 2001. The proposed standard will be based on the existing IEC/PAS 62111, "Specifications for the use of renewable energies in rural decentralised electrification" and, it is expected, IEEE P1547, "Standard for Distributed Resources Interconnected with Electric Power Systems".

Canada registering its pressure vessel standards to this new system.

Applications for stationary generators that are interconnected with a utility grid fall into the categories of either continuous or intermittent power. A continuous power application is one in which the generator operates, usually base loaded, with few interruptions. An intermittent generator is one that is intended to start periodically and run for a limited period of time, usually for peak shaving or acting as a back-up generator.

The type of application will influence the fuel source selection. Continuous operation will normally require a continuous fuel supply, such as that provided by the natural gas distribution network. Fuel tanks that are periodically recharged, on the other hand, may be more suitable for an intermittent generator, as continuous operation, though possible, may require large tanks.

When fuel storage tanks are used in intermittent power applications, or when a fuel supply is re-charged by another energy source, the fuel is likely to be hydrogen. Standards already exist in North America for hydrogen systems at consumer properties that are supplied by storage tanks. NFPA 50A, "Standard for Gaseous Hydrogen Systems at Consumer Sites" and NFPA 50B, "Standard for Liquefied Hydrogen Systems at Consumer Sites" cover gaseous and liquid hydrogen systems respectively, up to the point of the consumer interface.

The ISO TC197, "Hydrogen Technologies" committee is currently developing a set of international hydrogen standards. Although most of these standards relate to transportation, much of the same knowledge could be extended to stationary applications. For example, the draft document ISO/WD 15916, "Basic Requirements for the Safety of Hydrogen Systems" may be applicable to stationary applications.

The NFPA standards should be used in Canada for the short term, but, in the long term, developed into ISO standards through TC197, then adopted as Canadian National Standards. In contrast to the NFPA 50A and 50B standards, the scope of the proposed ISO standards should go beyond the point of consumer interface and include all equipment, from source to generator.

To date, continuous power fuel cell generators that are interconnected with the electric grid in Canada are using the natural gas distribution network as a fuel source. CSA B149.1, "Natural Gas and Propane Installation Code" is the gas installation standard applicable to these types of installations.

In addition to natural gas and hydrogen, there are several other fuel systems under consideration by the industry, some involving liquid fuels, both flammable and non-flammable. As the fuel technology develops, it is reasonable to expect additional standards work will be required in this area.

4.2 DC Generation

A standard is currently under development for DC fuel cell modules through IEC TC105. The IEC standards for stationary end-use applications will then reference this standard. The fuel cell module working group is led by the German delegation to IEC TC105.

4.3 DC to AC Conversion

UL revised the scope of UL 1741, "Inverters, Converters, and Controllers for Use in Independent Power Systems" on January 17, 2001, to include sources other than photovoltaics. The expectation is that this standard will begin to be used for stationary fuel cell generators in the near future. This will be further driven by the reference of this standard in IEEE P1547. Work is underway to harmonize IEEE P1547 and UL 1741 by 2003.

At the international level, IEC has started the development of a standard (IEC 62109) that will cover inverters and charge controller for use in photovoltaic systems. Much like with the UL 1741, an enlarged scope could serve other technologies as well, including fuel cell. Canada is contributing to the development of this IEC standard and has completed a review of the CSA C22.2 No. 107.1, "General Use Power Supplies" standard (see section 3.3.1 for status on CSA 107.1).

Also, IEC TC22, Power Electronics, includes this type of equipment within its scope. The strategic policy statement for TC22, specifically mentions the development of inverter related standards for fuel cells, photovoltaic and distributed generators as possible work items, once sufficient industry interest has been demonstrated.

Development of an IEC inverter standard and its adoption in Canada will take a few years. In the short term, the revised CSA 107.1, upon approval, will fill the Canadian need for such a standard.

4.4 Customer-side Interconnection

Equipment requirements for client side interconnection are presently given in the ANSI Z21.83, "Fuel Cell Power Plants"¹⁰, construction standard. This standard has been adopted as a national standard in the US. In Canada, CSA International has plans to publish CSA 12.10 as the Canadian equivalent to ANSI Z21.83. The IEC TC105 committee has started a project to write an IEC version of this construction standard that should be adopted by Canada once it is available.

The installation requirements for client side electrical interconnection are given in Section 84 of the Canadian Electrical Code. The balance of plant requirements (ventilation, exhaust, accessibility, fire protection, etc.) are provided in NFPA 853, "Standard for the Installation of Stationary Fuel Cell Power

10. This applies to production models. Field trial units are typically appraised using a "field acceptance" procedure.

Plants". The NFPA standard is primarily intended for fuel cell generators rated above 50 kW, however, it can be used as a guide for units below that size range.

Although a specific project has not yet been initiated, the US delegation to IEC TC105 has offered to lead the development of an IEC installation standard, based on NFPA 853. This IEC installation standard should be supported, then adopted as a Canadian standard, once available.

The following revisions to building and electrical codes are recommended:

- a) Provincial building codes should be revised to reference the IEC construction and installation standards once they are available.
- b) The Canadian Electrical Code, Part I Section 84, Clause 002, should provide an exemption for fuel cell generators installed in accordance with IEEE P1547.

As fuel cell technology continues to develop, the range of applications are likely to expand beyond base load and non-critical intermittent applications to include legally mandated emergency and stand-by generators. NFPA 110, "Standard for Emergency and Standby Power Systems" and CSA C282-00, "Emergency Electrical Power Supply for Buildings" are currently used for this purpose. The NFPA 110 standard, however, requires the energy source to be from a rotating machine. This standard will need revision, or a new one developed, for fuel cell generators used to supply emergency or stand-by loads. The CSA C282-00 standard may require modification to include any special considerations for fuel cells. In the event that an IEC project is initiated for emergency generators by another industry, Canada and the fuel cell industry should participate in such an effort.

4.5 Utility-side Interconnection

The requirements for utility side interconnection vary by province, or utility. The reference of the IEEE P1547 standard by Canadian utilities in their installation guides will lower costs by harmonising the technical requirements with those of the United States. For this reason, the Canadian utilities, or their regulatory boards, should be encouraged to adopt references to IEEE P1547.

The Joint Coordinating Group for TC 82/21/88 is planning to develop what is expected to be a wide-ranging interconnection standard with a global perspective. This standard is likely to have considerable long-term value for the fuel cell industry. For this reason, Canada should continue to participate in this committee and recommend that TC 105 become a formal member of the coordinating group. Once this standard is available, the electric utilities should be encouraged to adopt it as an alternate to the IEEE P1547 standard.

		Have in Canada	Need in Canada	Others (US or International)
FUEL SOURCE / STORAGE	Equip.	CSA B51 (pressure equipment)	Registration of CSA B51 standards with the ISO TC 11 equivalency committee	ASME Pressure Equipment Standards
	Installation	CSA B149.1 (natural gas installations)	ISO TC 197 - adopt standards applicable to stationary applications - develop equivalents to NFPA 50A, 50B	NFPA 54 (fuel gas code) ISO TC 197 (H2 committee) NFPA 50A, 50B (H2 Storage)
DC GENERATION	Equip.		Adoption of the IEC TC105 dc fuel cell module standard	IEC TC 105
	Installat.			
DC-AC CONVERSION	Equip.	CSA C22.2 No. 107-1 (power supplies) CSA 14 (Industrial Control Equipment)	IEC TC 22 inverter standard to take the place of the UL and CSA standards	UL 1741*
	Installat.	CEC Section 84 (interconnection)		NEC 692 (new section of the NEC for fuel cells under consideration for 2001).
CLIENT-SIDE INTERCONNECTION	Equip.	CSA/ANSI Z21.83	Adoption of the IEC construction standard	IEC TC 105 is now developing a standard for construction of stationary fuel cell generators
	Installation	CEC Section 84 (interconnection) CSA C282-00, "Emergency Electrical Power Supply for Buildings"	IEC installation standard based on NFPA 853 Reference IEC construction and installation standards in the Provincial building codes Add exception in CEC-84-002 for systems meeting IEEE 1547 Revise NFPA 110	NEC 692 NFPA 853 (installation of stationary fuel cell generators) NFPA 110 (emergency and stand-by generators)
UTILITY-SIDE INTERCONNECTION	Equip.	Varies by province / utility		
	Installation	Varies by province / utility	References to IEEE P1547 and eventually, the IEC equivalent in utility standards Add exception in CEC-84-002 for systems meeting IEEE 1547 and eventually, the IEC equivalent	IEEE P1547 Proposed IEC JCG TC 82/21/88

(*) Under consideration

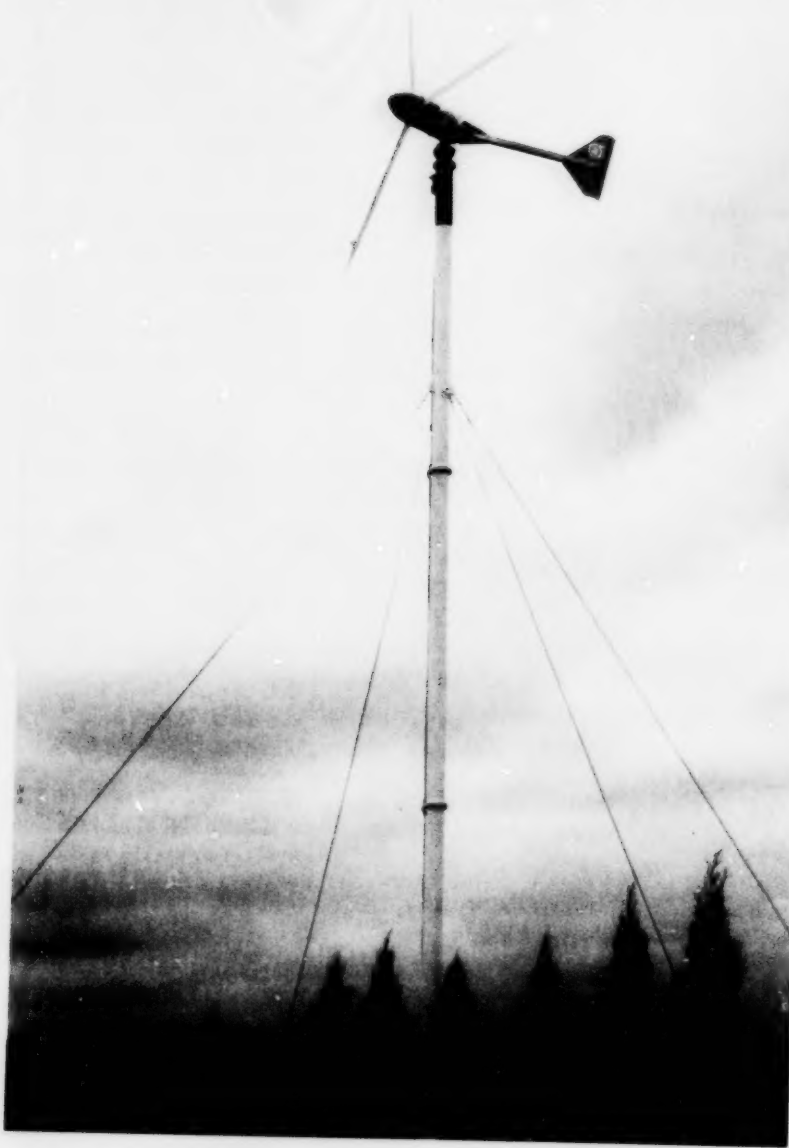


Photo courtesy of
Windstream Power Systems

A 10 kW grid-connected wind turbine providing power mainly for a gate house and the lighting of a parking lot at Kortright Centre for Conservation facilities located north of Toronto, Ontario.

A wind turbine allows to extract the kinetic energy of a moving air mass (wind) and convert it into useful energy, most often in the form of electricity. The electricity is produced by a generator that is driven by the rotor of the turbine. Such a generator produces AC power that is either rectified (DC) or synchronised with the grid.

5.0 Wind Technical Issues

Overview

Twelve years ago, Canada had successfully developed a range of "state-of-the-art" wind industry standards. Lacking, in the meantime, a viable Canadian wind turbine manufacturing industry and an equipment certification program, Canada's wind standards have languished and are not currently in commercial use.

During that time, the wind industry worldwide has been growing fast (over 20% per annum), and has now become a mainstream global renewable energy resource.

Published wind industry standards presently exist in Canada, the United States and Europe. The International Electrotechnical Commission Technical Committee 88 is responsible for the development of international standard and has 19 participating member countries (Canada does not participate but has an observer status.) Since the Canadian and US standards are generally ten or more years old, there are active movements in both these countries to adapt or adopt the more up-to-date IEC (International Electrotechnical Commission) TC88 standards for use in North America. In the United States, the National Renewable Energy Laboratory is working on a wind turbine certification program in conjunction with Underwriters Laboratories, using the IEC standards. In Canada, the Canadian Standards Association has requested that the industry reviews the current CSA and IEC wind standards in order to recommend a course of action.

Wind energy is very much a trans-national energy resource. All nationalities of wind turbine manufacturers sell, or wish to sell, their products everywhere in the world. Consequently every manufacturer would like to ensure that their product designs comply with applicable standards worldwide. Therefore there is a need for Canada to harmonize its standard to international standard or adopt IEC standards.

5.1 Fuel Source and Storage

Fuel Source

Wind is an energy resource that crosses national frontiers all over the world without official notice or regulation of any kind. Standards relating to worldwide wind energy resources include energy assessment (meteorological wind speed measurement, turbulence, gusts, wind shear). The safety component of energy assessment relates to the sizing and mounting of turbines with regard to the wind regime in which they will operate. This is important since wind turbine performance - and power quality - depends on the effective matching of the turbine to the site wind regime.

Existing Canadian and American standards for wind turbine siting include the following:

CSA F428-J (Site Assessment for Wind Energy Conversion Systems - Meteorological Aspects), is a "recommended practice" published in 1993 that describes procedures for evaluating the wind speed climatology of a site being considered for the operation of a wind energy conversion system so that its mean annual energy output and its uncertainty may be measured. Descriptions of other relevant meteorological elements such as turbulence and atmospheric icing are included.

AWEA 8.1 (Standard Procedures for Meteorological Measurements at a Potential Wind Turbine Site) provides procedures and methods for obtaining meteorological measurements at a site that has been proposed for wind energy use. Standards are provided for meteorological measurement systems and installation, operation and calibration of equipment. Guidelines for sampling strategies, data processing and site evaluation practices are given in the appendices.

AWEA 8.2 (Guidebook for the Siting of Wind Energy Conversion Systems) is a document providing guidelines for the proper siting of a wind turbine or group of turbines. These guidelines are recommended both for siting programs that begin with large scale land assessments as well as for site-specific applications where optimized wind turbine placement within a given parcel of land. This standard addresses such siting topics as meteorological measurements at candidate sites, instrumentation and wind flow modeling.

Canada lacks an actual wind measurement standard, despite its importance in the design and specification of wind turbines. The only way to predict the future energy production of a wind turbine is to know the average wind speed in which it will operate. Since the energy in the wind increases as the cube of the wind speed, a small change in average wind speed can account for a large change in future power production. Moreover, while seasonal variations do have to be taken into account, the measured average wind speed at any site remains virtually the same year in and year out, allowing accurate future energy supply projections and return on investment calculations to be made.

Fuel Storage

Wind energy, the kinetic energy carried by moving air, of which only up to about 60% can theoretically be converted into electricity, cannot be stored directly.

5.2 DC Generation

Except for the very smallest machines rated under 200 watts, all electric power-generating wind turbines produce three phase AC power. The very small DC machines are all used for charging batteries in small-scale remote power applications, such as cottages, camps, boats and RVs, and are never utility-interconnected.

Two principal types of generators are used in residential-scale wind turbines:

- A self-excited three-phase synchronous alternator, typically equipped with a permanent magnet field, produce an AC frequency output that varies with the turbine shaft speed, and is proportional to the wind speed. This then goes through a rectifier and is used to charge batteries, or else to directly power a static inverter (the rectified three-phase power is usually sufficiently smooth to reliably supply a line-commutated synchronous inverter).
- The induction generator, which is simply an induction motor directly connected to the grid, when rotated by the wind turbine faster than its synchronous motor speed, in effect forces power back into the grid. This type of auto-synchronized induction generator cannot function by itself in a stand-alone mode, because if the utility grid fails, the generator's internal magnetic fields cannot be sustained.

While simple in concept, this type of generator used in a wind turbine has several disadvantages: (a) since it must be turning at a specific speed, typically 1800 rpm, to commence generating, the energy in all wind speeds below that required to realize that rpm is lost; (b) it is limited in operating range, because too much torque applied to an induction generator causes it to break out of synchronization.

A wide range of standards related to electric generators exist outside of the wind industry standards and simply apply to wind generators. Therefore, there are no specific standards for wind turbine generators.

5.3 DC to AC Conversion

The static inverters referred to above are also subject to standards existing outside of the wind industry. CSA C22.2 / 107.1 is a Canadian power supply standard covering static inverters and there is a proposal to amend it for grid-interactive inverters (see PV section 3.3.1 of the report). In the United States UL 1741 specifically addresses such inverters used for photovoltaic systems but may also be applicable for other sources including small wind systems; this option is currently under evaluation. Similarly, UL 458 covers power converters and inverters for land and marine vehicles.

Because wind energy converters larger than the micropower range in this study are being designed with built-in power conversion systems, it is expected that a future IEC standard will be developed to address such systems.

5.4 Customer-Side Interconnection

This is the area in which wind standards are principally directed to safety and installation topics.

5.4.1 Equipment Standards

The following standards deal with wind turbine safety, design and performance testing issues:

CSA F416 (Safety, published in 1987) This standard specifies the requirements for the safety of wind energy conversion systems, including design and operation under specified environmental conditions. It is concerned with all subsystems, including protection mechanisms, supporting structures and foundations. It is concerned with the components and materials supplied by the manufacturers, with the adequacy of the assembly, installation, maintenance and operation instructions, and with the safety of the system after assembly when operated in accordance with those instructions.

CSA F417 (Performance, published in 1991) This standard specifies methods for determining and reporting performance characteristics for wind energy conversion systems. It applies to systems having mechanical, electrical or thermal output.

AWEA 1.1 (Performance, S93-700, 1988) This standard, comprising five sections, describes a standard method of determining and reporting primary performance characteristics of wind energy conversion systems. Sections include general information, field test method, noise treatment method, formulation of parameters and system performance test reports.

AWEA 3.1 (Design criteria, S93-702, 1988) This document describes the criteria to be used for the design of wind energy conversion systems. It consists of eight sections: scope and application of the document, applicable reference publications, significance and use of these criteria, general design criteria for wind energy systems, environmental and service condition design criteria, system design considerations, component design criteria, and mechanical, structural and electrical attachment conditions with other systems.

IEC 61400-1 (Wind Turbine Generator Systems - Safety Requirements, second edition, 1999) This standard deals with safety philosophy, quality assurance and engineering integrity, and specifies requirements for the safety of wind turbine generator systems, including design, installation, maintenance and operation under specified environmental conditions. Its purpose is to provide the appropriate level of protection against damage from all hazards from these systems during their planned lifetime. This standard applies to turbines with a swept area equal to or greater than 40m², and is concerned with all subsystems such as control and protection mechanisms, internal electrical systems, mechanical systems, support structures and the electrical interconnection equipment.

IEC 61400-2 (Safety of Small Wind Turbines, 1996) This standard deals with safety philosophy, quality assurance and engineering integrity, and specifies requirements for the safety of small wind turbine generator systems, including design, installation, maintenance and operation under specified

environmental conditions. Its purpose is to provide the appropriate level of protection against damage from all hazards from these systems during their planned lifetime. This standard applies to turbines with a swept area equal under 40m², and is concerned with all subsystems such as control and protection mechanisms, internal electrical systems, mechanical systems, support structures and the electrical interconnection equipment.

IEC 61400-12 (Wind Turbine Power Performance Testing, 1998) This standard specifies a procedure for measuring the power performance characteristics of a single wind turbine generator system, and applies to the testing of all types and sizes of wind turbines connected to the electric power network. It is applicable to the absolute power performance characteristics of a wind turbine and to differences between the power performance characteristics of various wind turbine configurations.

IEC 61400-13 (Measurement of Wind Turbine Structural Loads) This standard defines methods for measuring operational loads in wind turbines.

IEC 61400-23 (Wind Turbine Blade Structural Testing) This standard defines methods for wind turbine blade structural testing.

ASME PTC42 and ASTM E1240 are two additional US standards dealing with wind turbine performance and safety issues.

5.4.2 Installation Requirements

The safety and performance of a wind turbine system depends as much on the adequacy of the installation as it does on the safety considerations of the equipment. While wind energy system installation does not have a dedicated section in the Canadian Electrical Code, there are a few domestic and international standards that relate to wind turbine installation practices. These include:

CSA F-429 (Recommended Practice for the Installation of Wind Energy Conversion Systems, 1990) This standard provides recommended installation practices and procedures, and outlines the required specifications for the installation of wind energy conversion systems.

AWEA 6.1 (Recommended Practice for the Installation of Wind Energy Conversion Systems, S93-704, 1989) This document presents recommended practices for the installation of wind energy conversion systems, with regard to safety of installation personnel and the public. It is a general guide to be used with manufacturers' installation manuals and is organized to follow the installation process.

Lightning protection IEC 61400-24 (Lightning Protection for Wind Energy Conversion Systems) This document to be soon published as a standard describes lightning protection guidelines.

5.5 Utility-Side Interconnection

The technical requirements and standards for utility interconnection vary widely by utility and country. Generally, these requirements apply to relatively large-scale systems. There is a need for standards specifically addressing interconnection of the increasing number of small (residential-scale) private power systems. In the United States, two such standards are available, designed primarily for interconnection of photovoltaic systems, but also applicable to small wind power systems.

Non-utility-specific wind power interconnection standards include:

CSA F-418 (Interconnection to the Electric Utility): This standard was published in 1991 and specifies technical requirements for (a) the interconnection of a wind turbine to an electric utility; (b) the installation and operational specifications to be provided to the utility by those proposing interconnection to the utility; (c) the system protection including manual and automatic disconnect switches, transformers, fault protection devices, relays and other equipment for the safe interconnection to the utility; (d) isolation, startup and restart, and requirements related to the quality of power, e.g. limitations of harmonics, lamp flicker and power factor; (e) the installation of wind turbines in accordance with the requirements of the Canadian Electrical Code. This document has not been updated since its publication.

AWEA (Interconnection recommended practice 1988). Similar to CSA F-418.

IEEE 929 is a recommended practice for interconnection of photovoltaic systems which can also be applied to small wind power systems.

IEC 61400-21 is a standard covering interconnected power quality measurement techniques.

In Canada, the CEC section 84 deals generally with interconnection to utility grid, but specifically notes the authority of the individual utilities to apply their requirements.

In the majority of wind micropower grid connection projects, the interface will be a static inverter, as discussed in sections 5.3 above.

	Have in Canada	Need in Canada	Others (US or International)
FUEL SOURCE / STORAGE	CSA F-428J (Siting)	Updated Wind Measurement Standard	AWEA 8.1 (Wind measurement) AWEA 8.2 Siting)
DC GENERATION			
DC-AC CONVERSION	CSA C22.2 No. 107.1*	Larger Inverter Standard	UL 1741*
CLIENT SIDE INTERCONNECTION	CSA F-416 (Safety) CSA F-417 (Performance) CSA F-429 (Installation)	 Cold Weather Installation Guidelines	IEC 61400-11.1 (Safety) AWEA (Performance) IEC 61400-12 (Performance) AWEA 3.1 (Design) IEC 61400-2 (Small turbines) AWEA 6.1 (Installation) IEC 61400-11 (Noise) IEC 61400-24 (Lightning)
UTILITY-SIDE INTERCONNECTION	CSA F-418 (Interconnection) CEC, Section 84	Micropower Interconnection Standard	IEEE P1547 (Distributed Generation) IEC 61400-21 (Power quality)

* Under consideration



Photo courtesy of Mercury Electric Corporation

Microturbine unit providing 75 kW of electrical power as well as heat to a Health Canada Building in Toronto, Ontario.

A microturbine is a turbine powered electric generator that can run on various fossil fuel (liquid or gas) and provide energy efficient power. Microturbines also produce heat that can be used on-site and therefore provide an added value to the use of fossil fuel. Such turbines produce high frequency AC power that is rectified to DC before use or further conversion.

6.0 Microturbine Technical Issues: Safety, Power Quality, and Codes

Overview

Microturbine technology is much newer than either PV, Wind or Fuel Cells and there is not yet a manufacturer base that has started to develop standards as has been the case with the other technologies. The microturbine suppliers are participating in the IEEE P1547 process in the hope that this will reduce the interconnection barriers that the technology is facing in the United States. The main standard that suppliers are working with is UL 2200 – Stationary Engine Generator Assemblies. However there are a large number of associated standards in the United States which might be applied by various jurisdictions. The natural gas compressor, which will be required in many installations, has been of concern to gas companies although UL 2200 does cover this device. In the meantime, microturbine technology, although an inverter based technology, has been able to use codes originally developed for the stationary engine generator market.

6.1 Fuel Source and Storage

The standards which apply to the fuel storage, oil, propane or natural gas are those that apply to the supply of these fuels to existing stationary engine sets. The one component that has caused some delay in development is in the area of small gas compressors. Copeland has recently had their gas compressor listed using UL 2200. However Ontario currently has not listed UL 2200 on their list of approved standards, not because it has been rejected but because until now there has been no call for small gas compressors to be certified. The Technical Standards and Safety Authority (TSSA) has now struck a review committee that will be examining this issue.

6.1.1. Equipment Standards

There are numerous equipment safety standards that apply to fuel source equipment in microturbine systems, the following list includes some of the Canadian and international ones:

- CSA B51 - Boiler, Pressure Vessel and Pressure Piping Code (all components over 15 psig), boosters compressors
- Ontario Energy Act RSO 1990, Section 10
- ULC S643 - Aboveground, Shop Fabricated Steel, Utility Tanks
- ULC ORD-C404 - Pressure Indicating Gauges for Compressed Gas Sources
- ULC ORD-C25 - Meters for Flammable and Combustible Liquids and propane
- ULC S620 - Valves for Flammable and Combustible Liquids
- CSA C22.2 No199 - Combustion Safety Controls and Solid-State Igniters for Gas- and Oil-Burning Equipment
- IFGC 1997 - International Fuel Gas Code

6.1.2. Installation Requirements

With respect to installation, there exists some ambiguity around the training requirements to service microturbine fuel systems in Canada. Nevertheless the following codes and standards apply to the installation of the equipment:

- CSA B149.1 - Natural Gas Installation Code
- CSA B149.2 - Propane Installation Code
- CSA B149.3 - Code for the Field Approval of Fuel-Related Components on Appliances
- CAN/CGA B105 - Code for Digester Gas and Landfill Installation
- NFPA 30 - Flammable and Combustible Liquids Code
- NFPA 54 - National Fuel Gas Code
- NFPA 58 - Standard for Storage and Handling of Liquefied Petroleum Gases

6.2 DC Generation

In the case of microturbines, the generator provides high frequency AC which is rectified to DC. A number of standards were found that might be applicable but the principal ones would be UL 2200 and CSA C22.2 No. 107.1. General Use Power Supplies. The Canadian Electrical Code (CEC) Section 28-900 Protection and Control of Generators might also be used in this area. Also, Canada should be adopting or adapting C-UL2200, and other C-UL standards. These need to be universally accepted across all jurisdictions as uniformity of codes and their application is as important as their existence.

6.2.1 Equipment Standards

These are the Canadian and international standards known to be applicable for equipment standards with respect to DC generation:

- CSA C22.2 No107.1 - General Use Power Supplies
- UL 2200 - Stationary Engine Generator Assemblies
- IEEE 1159 - Recommended Practice for Monitoring Electric Power Quality
- EGSA 101N - Standard Nameplate Design for Engine Generator Set
(Under the purview of the Power Generation Components Subcommittee)

6.2.1 Installation Requirements

As far as the installation goes there are a number of standards, mainly international, that can be referenced:

- CEC Section 28-900 - Protection and Control of Generators
- UL 2200 - Stationary Engine Generator Assemblies
- IEEE 665 - Guide for Generating Station Grounding
- EGSA 100G - Performance Standard for Generator Set Instrumentation, Control and Auxiliary Equipment
(Under the purview of the Power Generation Components Subcommittee)

- EGSA 101P - Performance Standard for Engine Driven Generator Set (incomplete)
(Under the purview of the Power Generation Components Subcommittee)
- EGSA 100F - Performance Standard for Engine Protection Systems
(Under the purview of the Power Generation Components Subcommittee)

6.3 DC to AC Conversion

The main references here are the Canadian Standard CSA C22.2 107.1 (see section 3.3.1 for details) and the U.S. UL1741 standard, however there are other codes and standards which might be called upon by utilities and safety authorities. A single recognised inverter standard covering a large range of size would be useful.

6.3.1 Equipment Standards

The following are the Canadian and U.S. standards related to the equipment standard of DC to AC power converters.

- CSA C22.2 107.1 - General Use Power Supplies
- CSA C22.2 14 - Industrial Control Equipment
- CEC Section 84 - Interconnection of Electric Power Production Sources
- UL 1741 - Inverters, Converters and Controllers for Use in Independent Power Systems (under consideration)
- ANSI C84.1 - American National Standards for Electric Power Systems and Equipment Ratings
- IEEE Std.493 - Recommended Practice for Design of Reliable Industrial and Commercial Power Systems
- IEEE Std.519 - Recommended Practice and Requirements for Harmonic Control in Electric Power Systems
- ANSI/IEEE C37.20.1 - Standard for Metal-Enclosed Low-voltage Power Circuit Breakers Switchgear

6.3.2 Installation Requirements

The installation of static inverters is covered by the General Clause of the CEC Section 1-12, and 26). These sections cover general rules, grounding, wiring methods and general rules regarding installation of electrical equipment. There are no specific requirements for microturbine specified in the Canadian Electrical Code Part 1.

6.4 Customer-Side Interconnection

Numerous safety and power quality codes and standards that were originally developed for the installation of emergency power plants now apply to the installation of stationary power sources. However, most of the safety and control issues referenced in these codes refer to rotating generation, not static inverter-based technology.

6.4.1 Equipment Standards

- IEEE 902 - Guide for Maintenance, Operation and Safety of Industrial and Commercial Power Systems
- UL 1008 - Transfer Switch Equipment
- CSA C22.2 No.229 - Switching and Metering Centres

- ANSI C37.54 - Standard for Switchgear-Indoor Alternating-Current High-Voltage Circuit Breakers Applied as Removable Elements in Metal-Enclose Switchgear Assemblies-Conformance Test Procedure

6.4.2 Installation Requirements

- CEC Section 84-00 - Interconnection of Electric Power Production Sources (installation of consumer-owned electric power generation)
- CSA C282-00 - Emergency Electrical Power Supply for Buildings
- NFPA 37 - Standard for the Installation and Use of Stationary Engines and Gas Turbines
- ASME B133.8 Gas Turbine Installation Sound Emission
- NFPA 70 National Electrical Code, Article 705 - Interconnected Electric Power Production Sources
- NFPA 110 - Standard for Emergency and Standby Power Systems
- NFPA 101, Chapter 5 - The Life Safety Code
- NFPA 99 - Standard for Health Care Facilities
- IEEE C37.95 - Guide for Protective Relaying of Utility Consumer Interconnections
- IEEE C62.92.4 - Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part IV - Distribution
- ANSI C12.20 - Electricity Meters 0.2 and 0.5 Accuracy Classes

6.5 Utility-side Interconnection

The most active Canadian utility/supplier group dealing with these issues is the Alberta Distributed Generation Technical Committee, which is preparing an interconnection guideline for distributed generation. The equipment of interest in the inverter area has been microturbines that are using flare gas. However, some suppliers are interested in larger gas fired equipment. IEEE P1547 is referenced in these guidelines. It is considered important that Canadian utilities standardise their interconnection guidelines so that suppliers do not have to deal with many different varieties of interconnection standards.

6.5.1 Equipment Standards

Section 84-002 of the CEC - Interconnection of Electric Power Production Sources stipulates that the interconnection shall be in accordance with the requirements of the supply authority. This has lead to different requirements being prepared on a need basis; therefore varying from one utility to the other.

6.5.2 Installation Requirements

Two U.S. standards are mentioned as references. Canada still lacks that sort of document for interconnection; the adoption or adaptation of the IEEE P1547 or an international equivalent should be considered.

- IEEE P1547 - Standard for Distributed Resources Interconnected with Electric Power Systems – currently in a draft form
- IEEE C37.95 - Guide for protective Relaying of Utility-Consumer Interconnections

		Have in Canada	Need in Canada	Others (US or International)
FUEL SOURCE / STORAGE	Equip.	CSA B51 ULC S643 ULC ORD-C404 ULC ORD-C25 CSA C22.2 No. 199 Ontario Energy Act RSO-Section 10		IFGC 1997
	Installat.	CSA B149.1 CSA B149.2 CSA B149.3 CAN/CGA B105		NFPA 58 NFPA 30 NFPA 54
DC GENERATION	Equip.	CSA C22.2 No. 107.1	Canadian standard equivalent to UL 2200	UL 2200, Section 34 IEEE 1159 EGSA 101N
	Installat.	CEC 28-900		UL 2200 IEEE 665 EGSA 100G EGSA 101P EGSA 100F
DC-AC CONVERSION	Equip.	CSA C22.2 No. 107.1* CSA C22.2 No. 14		UL 1741* ANSI C84.1 IEEE Std. 493 IEEE Std. 519 ANSI/IEEE C37.20.1
	Installat.	CEC Section 1-12, and 26		
CLIENT-SIDE INTERCONNECT	Equip.	CSA C22.2 No. 229		IEEE 902 UL 1008 ANSI C37.54
	Installat.	CEC Section 84-002 CSA C282-00		NFPA 37 ASME B 133.8 NFPA 110 NFPA 70 NFPA 101, Chapter 5 NFPA 99 IEEE C37.95 IEEE C62.92.4 ANSI C12.20
UTILITY-SIDE INTERCONNECTION	Equip.	CEC 84-002		
	Installat.		National standard or guidelines on interconnection	IEEE P1547* IEEE C37.95

* Under consideration

7.0 Summary

This table provides a summary of existing safety codes, standards and guidelines relevant to the installation of static inverter-based micropower systems in Canada. Also, since international references are commonly considered, they have been included here.

	PV		Fuel Cell	
	Domestic	International	Domestic	International
SOURCE / STORAGE			CSA B51 CSA B149.1	ASME Pressure Equipment Standards NFPA 54 NFPA 50A, 50B ISO TC 197
DC GENERATION	CEC 50-004 to 50-020* CSA 107.1 clause 14*	NEC 690-4 to 690-53 ULC-1703* IEC 61730		IEC TC 105
DC-AC CONVERSION	CEC 1-12, 26 general requirements CSA 107.1 clause 15*	IEC 62109 UL 1741	CSA 107.1* CSA 14	NEC 692 UL 1741*
CLIENT-SIDE INTERCONNECT	CEC Part II relevant standards CEC 50 clause 022*	NEC 690-54 to 690-64	CEC 84 CSA/ANSI Z21.83 CSA C282-00	NEC 692 NFPA 110 NFPA 853 IEC TC 105
UTILITY-SIDE INTERCONNECT	CEC 84 Local Requirements	IEEE 929 IEEE P1547*	Local Requirements	IEEE P1547* IEC JCG TC 82/21/88*

(*) Under consideration

Wind		Microturbine		
Domestic	International	Domestic	International	
CSA F-428J	AWEA 8.1 AWEA 8.2	CSA B51 CSA 199 Ontario Energy Act RSO-Section 10 CSA B149.1 CSA B149.2 CSA B149.3 CAN/CGA B105	NFPA 30 NFPA 54 NFPA 58 ULC S643 ULC ORD-C25 ULC ORD-C404 IFGC 1997	SOURCE / STORAGE
		CSA 107.1* CEC 28-900	UL 2200 UL 2200, Section 34 IEEE 665 IEEE 1159 EGSA 100F EGSA 100G EGSA 101N EGSA 101P	DC GENERATION
CSA 107.1*	UL 1741*	CSA 107.1* CSA 14	ANSI C84.1 ANSI/IEEE C37.20.1 UL 1741* IEEE Std.493 IEEE Std. 519	DC-AC CONVERSION
CSA F-416 CSA F-417 CSA F-429	AWEA 1.1 AWEA 3.1 AWEA 6.1 IEC 61400-1 IEC 61400-2 IEC 61400-11 IEC 61400-11.1 IEC 61400-12 IEC 61400-24	CEC 84-002 CSA C282-00 CSA 229	ANSI C12.20 ANSI C37.54 ASME B 133.8 NFPA 37 NFPA 70 NFPA 99 NFPA 101, Chapter 5 NFPA 110 UL 1008 IEEE C37.95 IEEE C62.92.4 IEEE 902	CLIENT-SIDE INTERCONNECT
CEC 84 CSA F418	IEEE P1547* IEC 61400-21	CEC 84	IEEE C37.95 IEEE P1547*	UTILITY-SIDE INTERCONNECT

8.0 Conclusion

From a general perspective, micropower technologies share a number of common issues, and these can be addressed regardless of the generation method. Among all those listed in the Summary Table (section 7.0), the two that stand out as common to all are:

- The need for a static inverter standard covering grid-interconnection aspects with the use of any micropower generation. The CSA standard currently under consideration for upgrade will cover grid-tied inverters for up to about 25 kVA (under consideration). There will likely be a need for standards on static inverters larger than 25 kVA. The value of such a standard is that it assures that specific safety aspects, with respect to interconnection for instance, have been considered. Authorities can then recognize a product carrying this label as safe and acceptable, and may find the built-in protections for anti-islanding to be sufficient.
- The need for a Canadian interconnection guideline/standard that covers all micropower technologies.

One common trend for all of these technologies is the interest in adopting international standards, namely IEC's, as opposed to the development of domestic standard, whenever possible.

Much like the computer industry, which started out using mainframes that were huge, expensive, complex and limited in function and resulted in the evolution of computers that are now available as small, inexpensive, easy-to-use devices with amazing capabilities, the distributed generation will only become more popular and accessible through development of safe, standard products. In other terms, standards play a key role in addressing many of the needs for safety, power quality, lower cost, uniform regulation and education; the following reviews their importance with respect to these specific aspects.

Safety: Generators and connections must present no greater risk of fire or electrical shock than other devices already approved for use in homes and businesses. Requirements for equipment, wiring, installation and inspection must be in proportion to the size and inherent risks of the system. Standards intended for large industrial units may be unreasonably strict and better adapted requirements may be needed in some instances.

Interconnection devices must stop the supply of electrical current from micro generators to the main grid in the event of a power failure. This is essential to protect utility workers from unexpected live wires while making repairs. Utilities must be aware of micropower sources and develop safety procedures to protect workers in the event power enters the grid due to equipment malfunction. Regulators must decide whether it is worth the cost for each generator to have an outdoor manual disconnect switch, allowing utility workers to lock out unwanted current.

Power Quality: Standards will ensure that different manufacturers, and different generation technologies, all produce consistently high-quality AC current. This will avoid damage to other electrical devices at the site, and disruption of power quality on the grid.

Lower costs: Manufacturing standards must be set to ensure safety and reliability, while not erecting unreasonable barriers to commercial production. Uniform installation standards will allow for better market penetration, higher volumes, more research and more competition, all of which will drive costs down.

As more systems are installed, it will become more time-consuming and expensive for utilities to inspect, analyze and approve individual sites. Standards will simplify installation and reduce the cost of inspections.

Uniformity of Regulation: While a national Canadian strategy is being pursued, and consistent international standards are desirable, legal authority for regulation of the micropower industry rests primarily at the provincial level. It is important that provincial regulators understand the importance of adopting national or international standards, and of enforcing consistency within their jurisdictions.

Education: Many electrical and building inspectors are not familiar with micropower and interconnection issues, and may be reluctant to approve some installations. Once standards have been harmonized, there should be a significant effort to inform front-line workers throughout the industry.

Finally: Global demand for small, environmentally friendly power systems is rapidly accelerating. In Canada, there is a huge potential market among homeowners and small business operators. The opportunity exists for Canada's economy to benefit substantially through the connection of these systems. Small power systems have the potential to reduce Canada's dependence on fossil fuels as well as environmental damage related to coal or oil-fired generation, and provide greater security in the event of energy shortages. In addition, the micropower market could provide thousands of jobs and billions of dollars in revenue.

The challenge now is for the governments and industry regulators to allow this new, evolving industry to grow in a way that is both safe and efficient.

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Acronyms used in this report

AC	Alternating Current
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWEA	American Wind Energy Association
CANMET	Canada Centre for Mineral and Energy Technology
CEC	Canadian Electrical Code, Part I
CEDRL	CANMET Energy Diversification Research Laboratory
CSA	Canadian Standards Association, now CSA International
DC	Direct Current
EFC	Electro-Federation Canada
EGSA	Electrical Generating Systems Association (U.S.A.)
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IFGC	International Fuel Gas Code
ISO	International Organisation for Standards
JET	Japan Electrical Testing
NEC	National Electric Code (U.S.A.)
NFPA	National Fire Protection Association (U.S.A.)
NSSN	National Standards System Network (U.S.A.) see ASME, ASTM, IEEE
NRCan	Natural Resources Canada
ORD	Other Recognised Document
PV	Photovoltaic (Solar electric modules)
SCC	Standards Council of Canada
TC	Technical Committee
THD	Total Harmonic Distortion
TUV	Technical Inspection Association (Germany)
UL	Underwriters' Laboratory (U.S.A.)
ULC	Underwriters Laboratory of Canada

Units

W	watts
Hz	hertz
kW	kilowatt
kWp	kilowatt peak
kVA	kilovolt-amperes
MW	megawatt
psig	pounds per square inch gauge